Connecting Cost Estimating and EVM with Continuous Cost-Risk Management

Briefing to

NASA Program Management Challenge Conference

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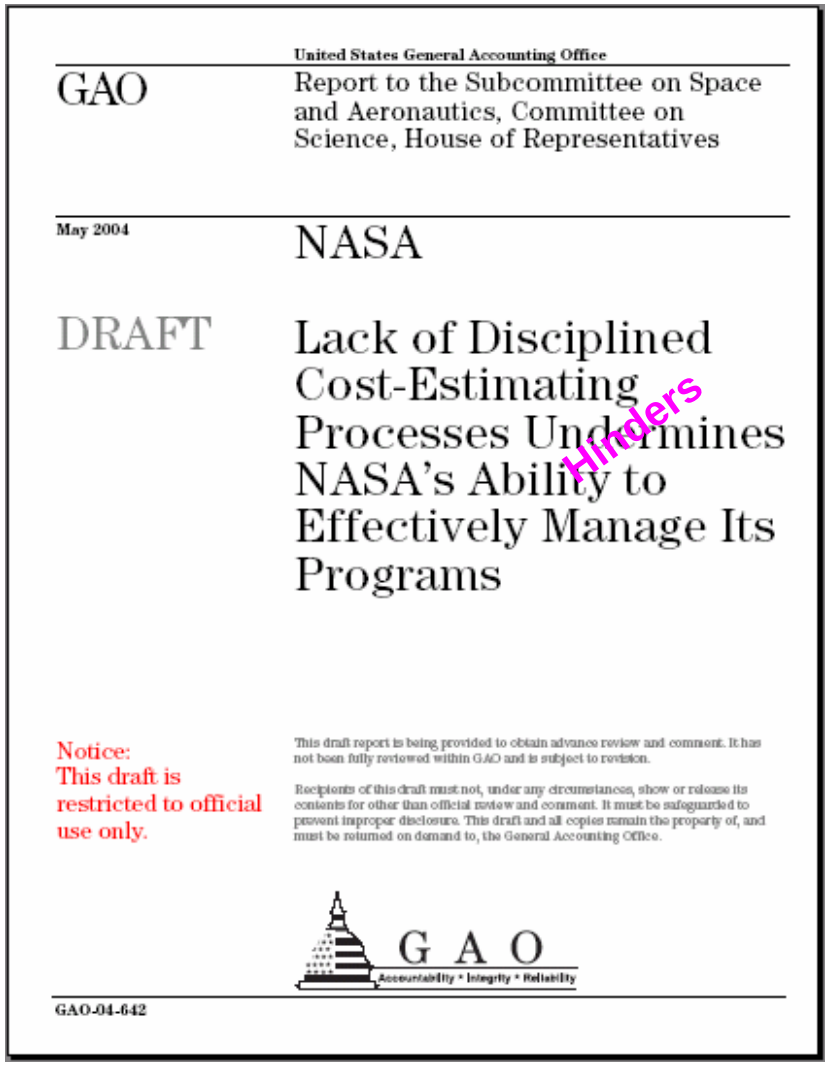
Outline

- **2004 GAO and Aldridge Commission Reports**
- **NASA responses**
  - Cost Initiatives: Continuous Cost-Risk Management (CCRM)
    - Emphasis on identifying, quantifying and managing cost-risk
- **Cost-risk assessment and analysis**
  - Cost estimating relationship risk
  - Cost model input parameter/driver risk
  - Key system/subsystem/WBS element characteristic risk
  - Correlation
- **Linking Estimating Cost-Risk to EVM**
  - EVM Cost Performance Report (CPR) Data Item Description (DRD)

2004 GAO Report on NASA Cost Estimating

- **Scope included 27 projects**
  - Median cost growth of 13%
  - (Absolute mean deviation of 26%)
- **Recommendations**
  - Develop an integrated plan including
    - Guidance for rebaselining
    - Enforced use of Earned Value Management
    - Staff and support for cost-estimating and EVM
  - Establish a standard framework for Life Cycle Cost Estimates
    - Based on a full Life Cycle Cost
    - Using a WBS encompassing both in-house and contractor efforts
    - Using CARDs
    - With Independent Cost Estimates at each milestone
    - Using cost risk assessments
  - Prohibit projects from proceeding through the review and approval process without above



United States General Accounting Office

GAO

Report to the Subcommittee on Space and Aeronautics, Committee on Science, House of Representatives

May 2004

NASA

DRAFT

Lack of Disciplined Cost-Estimating Processes Undermines NASA's Ability to Effectively Manage Its Programs

Hinders

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G A O
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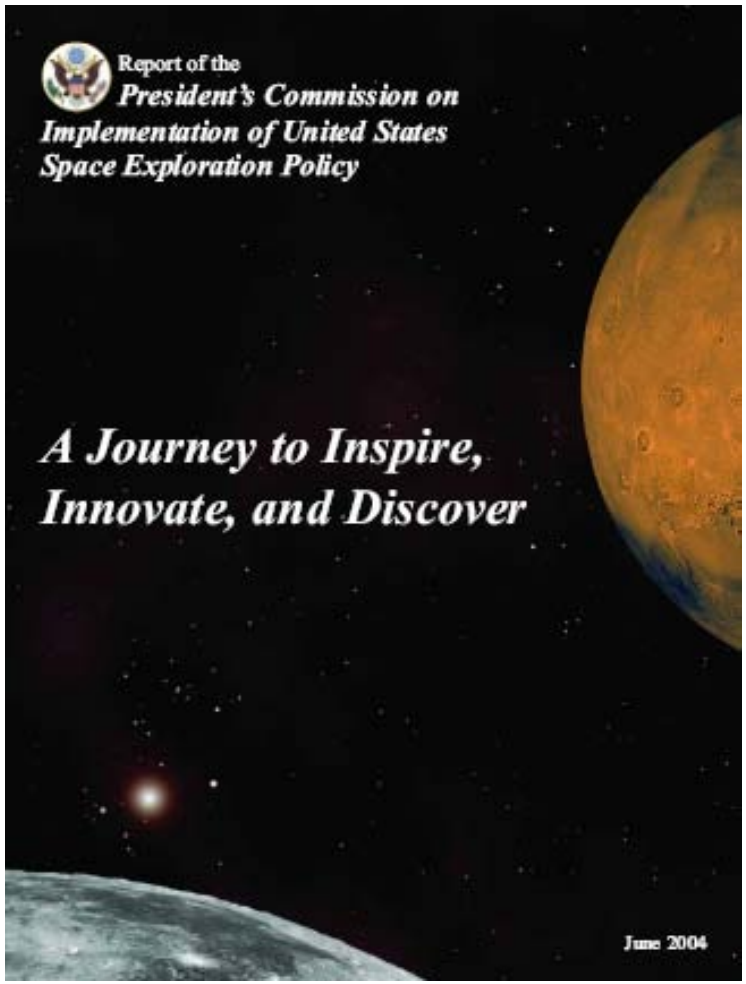
GAO-04-642

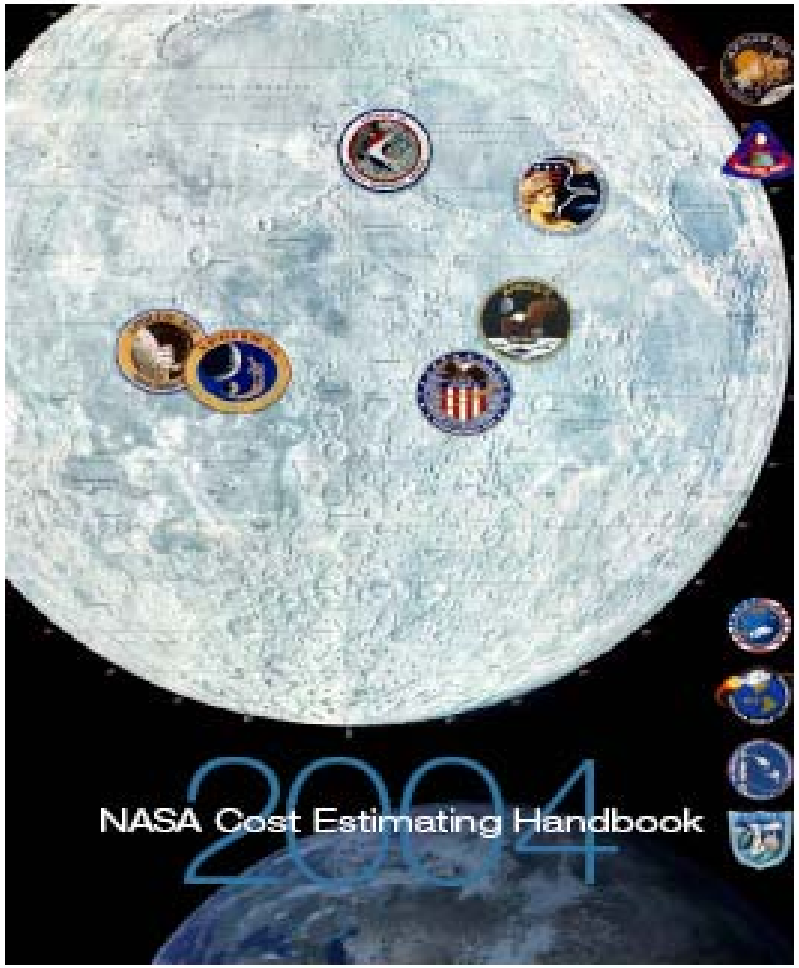
2004 Aldridge Commission Recommendations On NASA Cost Estimating

- **Recommended an independent cost analysis organization similar to DoD CAIGs (Cost Analysis Improvement Group)**
  - Independent cost estimating organization
  - Maintains corporate data base of historical project cost information
  - Generally uses parametric cost estimating procedures
  - Recommends final cost position to approving bodies



Cost Initiatives

- **Initiatives to improve Agency cost estimating are documented in the new NASA Cost Estimating Handbook (www.ceh.nasa.gov) which is tied closely to NPR 7120.5C**
- **The initiatives include:**
  - Use of Continuous Cost Risk Management (CCRM) to improve coordination across cost communities of practice (estimating, EVM, project management, procurement, etc.)
  - The use of cost risk analysis to quantify uncertainty
  - Better cost data collection using a Cost Analysis Data Requirement (CADRe)
  - A corporate data base of CADRes – the One NASA Cost Engineering (ONCE) database

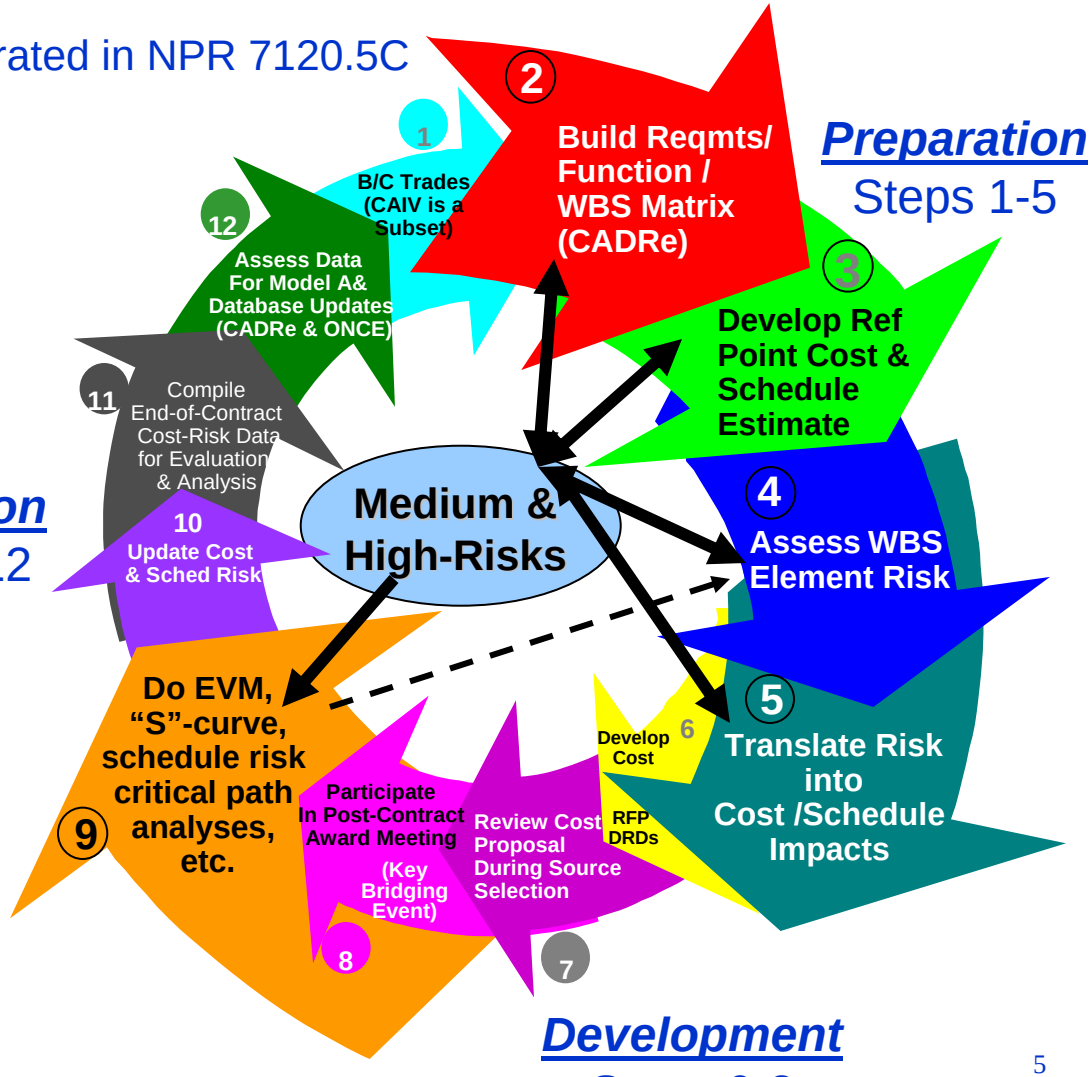


Connecting Estimating and EVM with *Continuous Cost-Risk Management (CCRM)*

A cost management architecture providing:

- **Early id & cost impacts of medium- and high-risk WBS elements in cost estimate**
- **Communication of WBS element risk to project managers for focused cost management**
- **Post-cost estimate tracking of identified WBS element risk *using EVM system***
- **Update, collection and archiving of technical data, cost data and cost-risk data for cost model improvement**

Incorporated in NPR 7120.5C

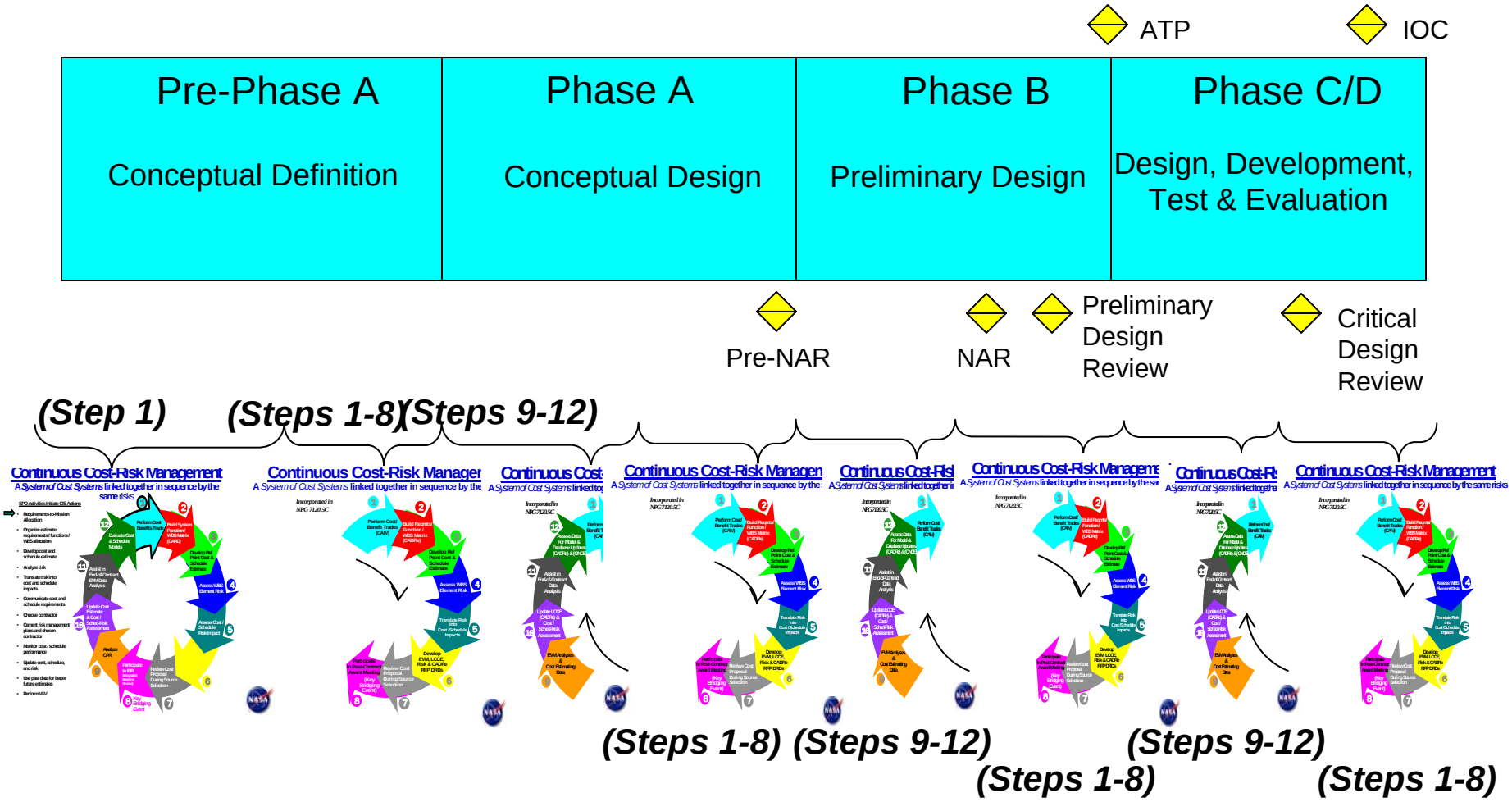


Preparation
Steps 1-5

Application
Steps 9-12

Development
Steps 6-8

CCRM Repeats in Each Project Phase



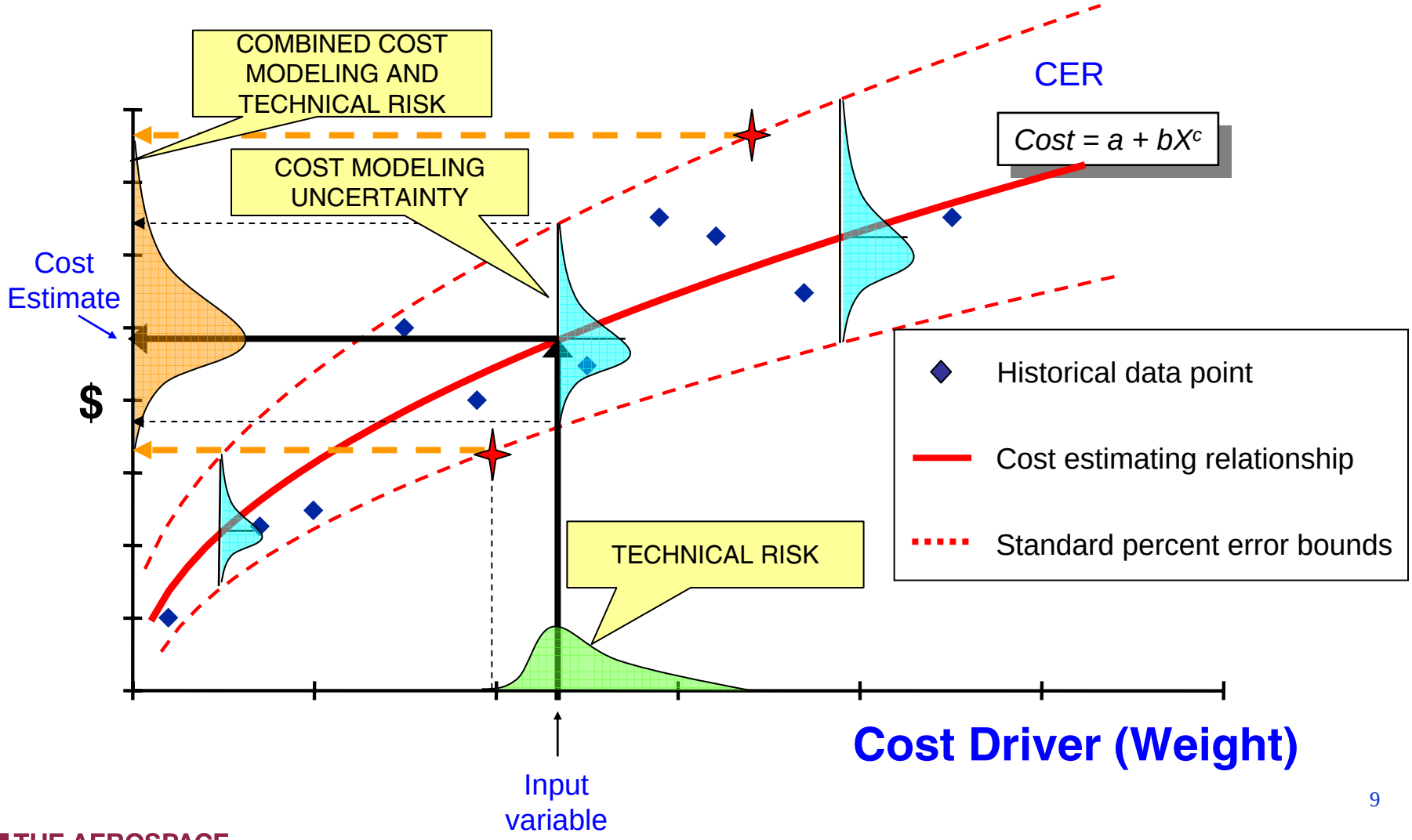
Point vs Range Estimates

- **Being precise about point estimates is next to impossible**
- **However, range estimating is eminently possible**
- **RRW produces range estimates**
  - Highest point on curve not going to happen
  - Lowest point on curve not going to happen
  - Somewhere in between will happen

Cost-Risk Assessment & Analysis
(CCRM Steps 4&5)

- **Assessment**
  1. ***Cost model uncertainty***
     - Cost estimators handle this
  2. ***Input parameter uncertainty***
     - Engineering assessment needed
  3. ***Key System/Subsystem/Element Characteristic uncertainty***
     - Key Engineering Parameter Performance (KEPP); Key Management, System Engineering, etc., Characteristics
     - 3 risk profiles (pessimistic, optimistic & reference) evaluated in terms of cost-risk drivers
  4. ***Correlation uncertainty***
     - Engineering/cost estimator assessment needed
- **Analysis**
  – Convolve all distributions for “S”-curve (CDF)

Cost Model and Input Parameter Uncertainty Cost Quantification (CCRM Steps 4&5)



Key System/Subsystem/Element Characteristics

- **Key Engineering Performance Parameters[1] (KEPPs) for new electronic component for a S/C**
  - Dynamic load resistance
  - Operating voltage
  - Power regulation
  - Radiation resistance
  - Emissivity
  - Component mass
  - Operating temperature range
  - Operating efficiency

[1]The Technology Puzzle: Quantitative Methods for Developing Advanced Aerospace Technology; Liam Sarsfield (RAND)

Key System/Subsystem/Element Characteristics

- **KEPPs for a Laser/Amplifier Transmitter**
  - Wave front sensing
  - Wave generation
  - Mirror coatings and gratings
  - Autonomous resonator alignment
  - Bore sighting
  - Electrical power generation

Key System/Subsystem/Element Characteristics

- KEPPs for Test & Integration
- I&T procedure design
- Installation H/W design/manufacture
- Acceptance operations
- Contractor/sub interfaces
- Number of ICDs
- etc.

Key System/Subsystem/Element Characteristics

- **Key Management Characteristics (KMCs)**
  - Experience of personnel
  - Risk management effort levels
  - Earned Value Management implementation level
  - Management structure (IPT, functional, matrix, etc.)
  - etc.

Key System/Subsystem/Element Characteristics

- **Key System Engineering Characteristics (KMCs)**
  - Level of system engineering expertise
  - Percentage of system engineering performed early
  - Tools used for requirement/function allocation
  - Logistics considerations
  - Planning, monitoring, measuring, B/C studies, etc.
  - Percentage of system engineering performed during effort

Key Characteristic Risk

(CCRM Steps 4&5)

Risk Rating Matrix

WBS ELEMENT PROFILES	TECHNLGY	DES/ENG	COMPLEXITY	SCHEDULE	TOTAL
	0.35	0.25	0.2	0.2	1.0
1. PESSIMISTIC PROFILE	HIGH	VERY HIGH	VERY HIGH	HIGH	5.9
2. REFERENCE PROFILE	MOD	MOD	MOD	MOD	2.9
3. OPTIMISTIC PROFILE	LOW	MOD LOW	MOD	MOD	2.0

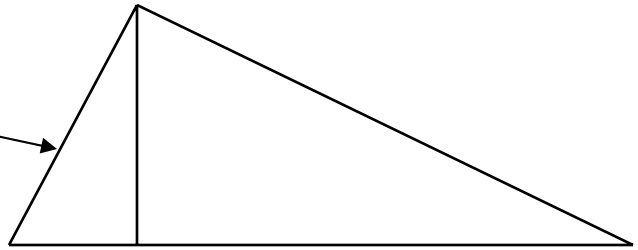
Cost-risk categories (could be more)

$$\frac{\text{PESSIMISTIC “SCORE”}}{\text{REFERENCE “SCORE”}} = \frac{5.9}{2.9} = 2.0 = \text{HIGH END RISK FACTOR For Key Characteristic Risk}$$

$$\frac{\text{OPTIMISTIC “SCORE”}}{\text{REFERENCE “SCORE”}} = \frac{2.0}{2.9} = 0.7 = \text{LOW END RISK FACTOR For Key Characteristic Risk}$$

THESE FACTORS ARE THEN APPLIED TO THE RPE TO OBTAIN THE “LOW AND HIGH END” COSTS

Translation To Cost



0.7 * RPE RPE
(“LOW END” COST)

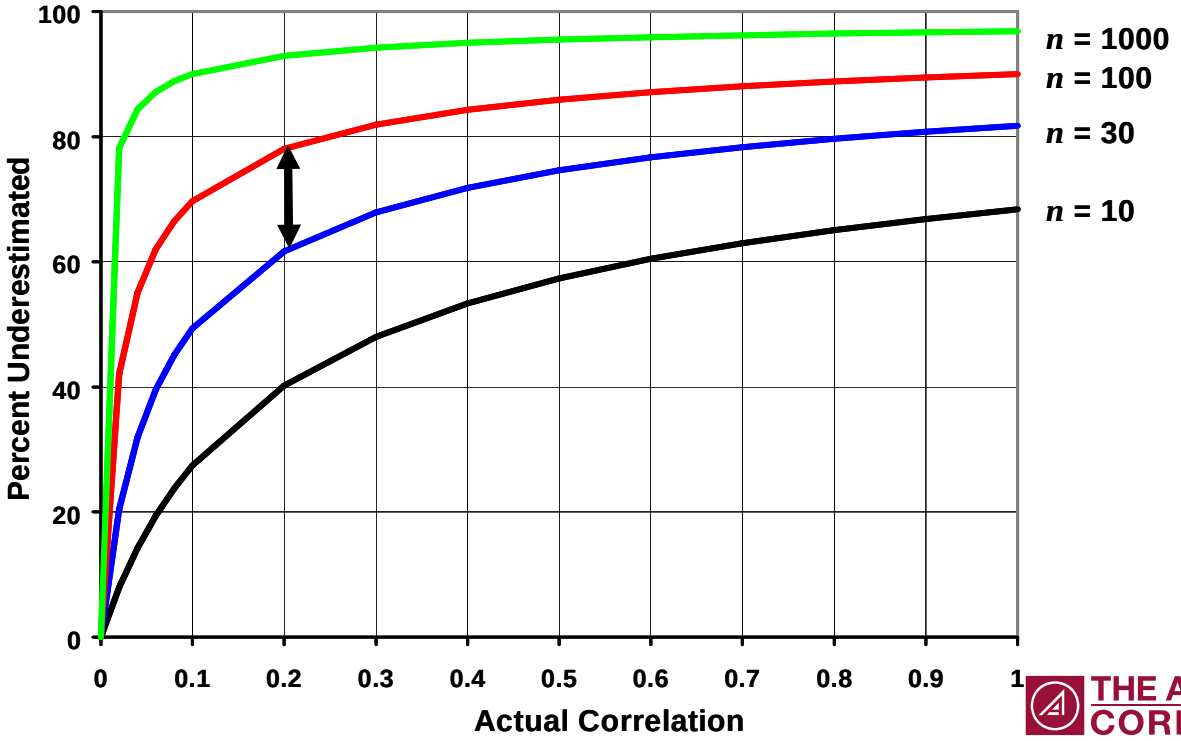
2.0 * RPE
(“HIGH END” COST)

Correlation

(CCRM Steps 4&5)

- **Dr. Stephen Book (MCR) plotted the theoretical underestimation of percent total cost standard deviation (y-axis) when correlation (x-axis) is assumed to be zero rather than its true value, ρ.**
  - In cost estimates we would underestimate % SD ~60%-80% if we ignored correlation and it was actually 0.2

% Underestimated Theoretical Total Cost Standard Deviation

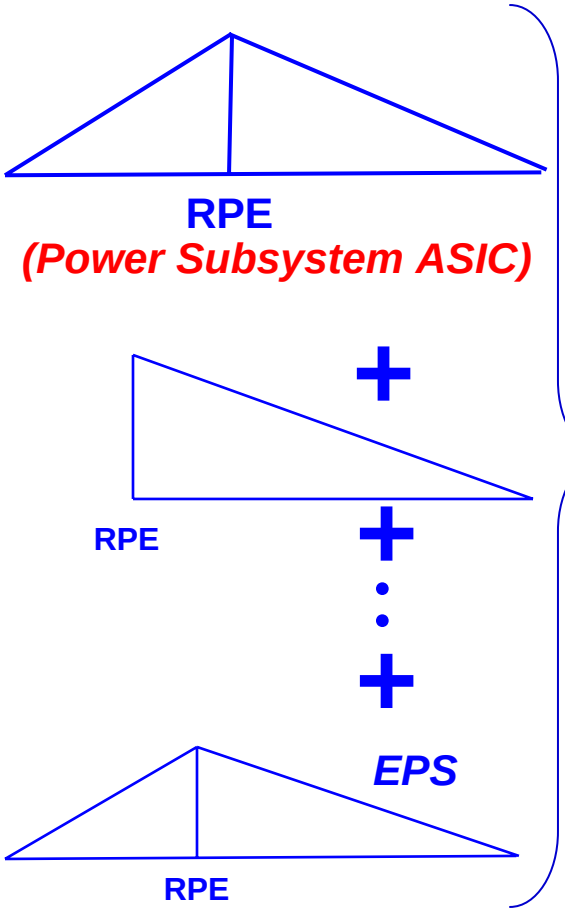


From: 1999 Cost Risk Analysis Seminar, Manhattan Beach, CA

Cost-Risk Analysis: Convolution

(CCRM Step 5)

CORRELATED SUBSYSTEM COST DISTRIBUTIONS:



CER, Parameter Input, and KEPP Cost-Risk Distributions on Lower Level WBS Elements

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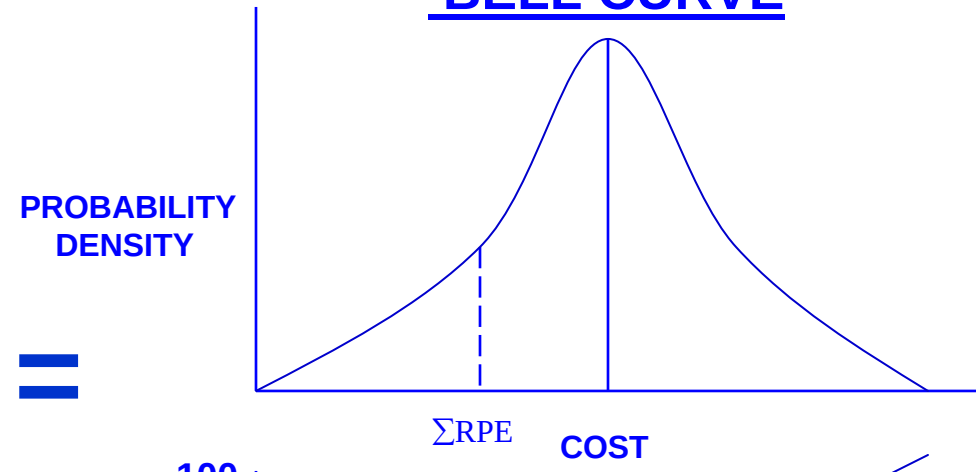
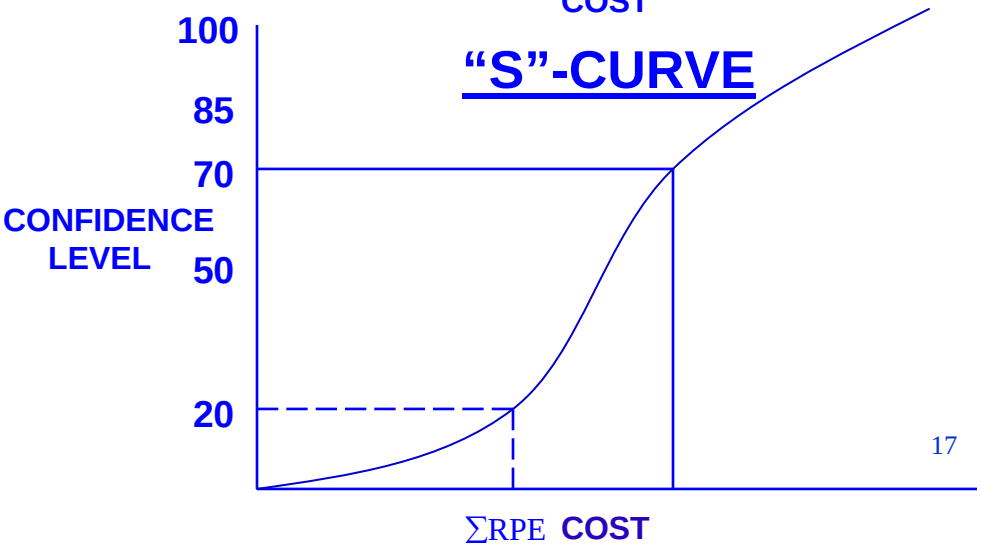
SUMMARY COST DISTRIBUTIONS: BELL CURVE

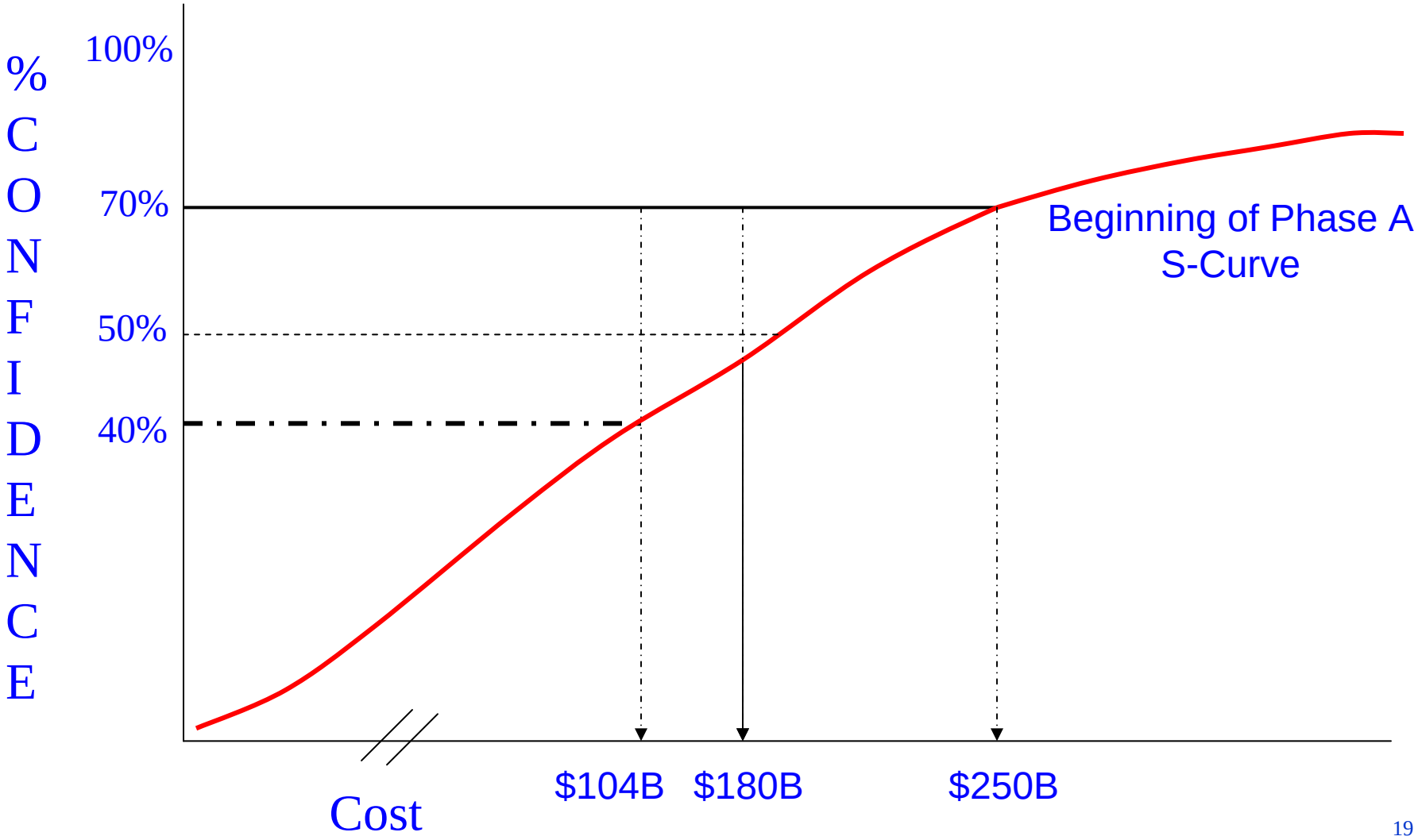


"S"-CURVE

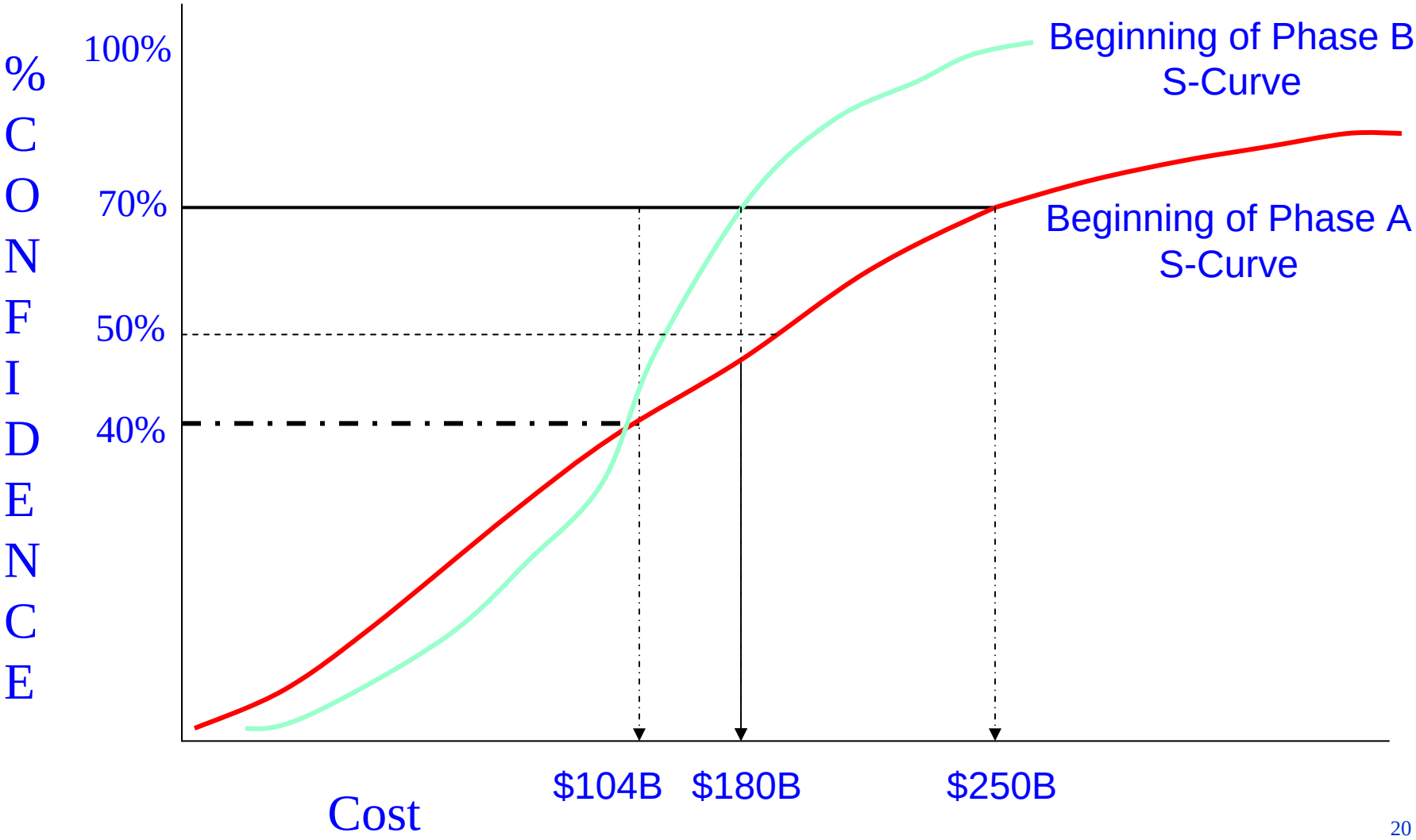


Risk Management Metric

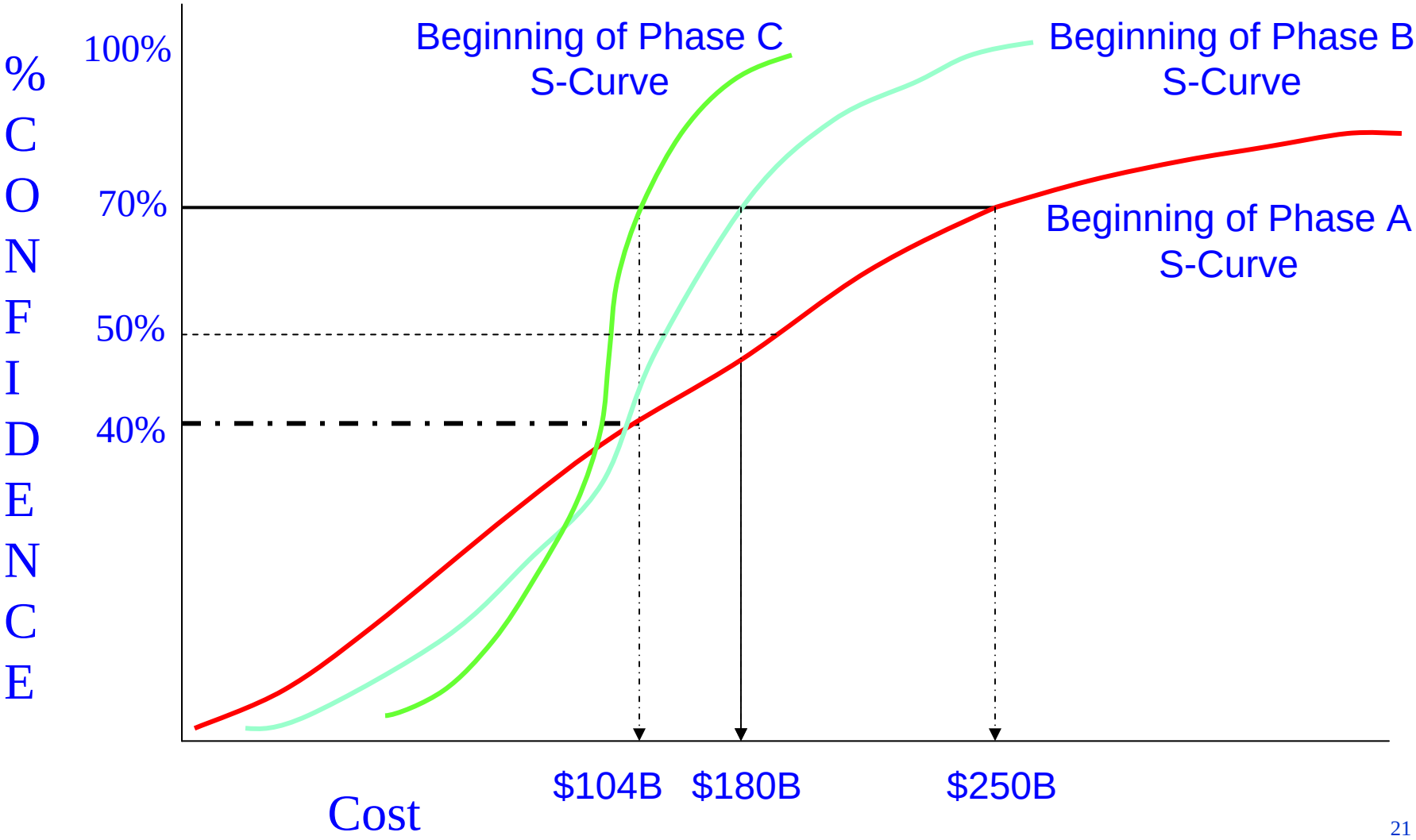
S-Curve Migration with Good Risk Management



S-Curve Migration with Good Risk Management



S-Curve Migration with Good Risk Management



Linking Estimating Cost-Risk to EVM

- The work of cost estimation/cost-risk assessment and analysis is communicated to the EVM community through implementing CCRM steps 6-8
- NPR 7120.5C (paragraph 3.4.3.2a(6)) requires medium and high-risk WBS elements identified in the government cost estimate to be listed in the EVM CPR Data Requirement Description and/or the Project Plan
- EVM Working Group has recently completed a CPR DRD Guidance Document and a recommended CPR DRD template for use by the project RFP developers and Project Plan drafters

CPR Data Requirements Description
(CCRM Step 6)

- **For cost-risk feedback, the contractor or performing organization needs to be informed in the RFP/Project Plan about:**
  - Medium and high-risk systems, subsystems and/or WBS elements identified initially in the cost estimate
  - EVM performance measurement requirements against these specific risky WBS elements
    - e.g., WBS element reporting levels (NPR 7120.5C)
- **An EVM CPR DRD template is available on the Cost Estimating Handbook website**
  - www.ceh.nasa.gov

Key CPR DRD Language

- "Earned value performance measurement data for government-identified medium and high-risk WBS elements (see list below), if available and appropriate, shall be reported on Formats 1 & 2 of the monthly CPR until such time as both government project management and the contractor agree that they no longer represent medium or high risks"
- "This reporting on medium and high-risk WBS elements shall be at a level that is adequately sensitive to performance measurement indicators to ensure earliest identification of cost and schedule problems caused by the source risks (e.g., level 5, 6, or 7 or just above control account level)"
- "Narrative variance analysis is not required for this level of medium and high-risk elements"
- "The contractor shall identify all known medium and high-risk WBS elements specific to his design, if not provided in the list above, and report their performance measurement on CPR Formats 1 & 2"

Example of Earned Value DRD Instructions
Paragraph 1: High Risk WBS List & Reporting Criteria
(CCRM Step 6)

1. Earned value insight (BCWS, BCWP, ACWP on Format 1 and narrative status on Format 5) for the following high risk WBS elements shall be provided every month regardless of variance percentage levels until the system program office (SPO) informs the contractor otherwise:

Power Subsystem ASIC; Solar Power Converter; Pointing & Control System Laser Amplifier/Transmitter; Laser Transmit Antenna; Microwave Receive Antenna; Laser Receive Antenna; Tracking & Control System; Laser Conditioning Receiver; Laser Rectifier/Converter; Flywheel Storage System

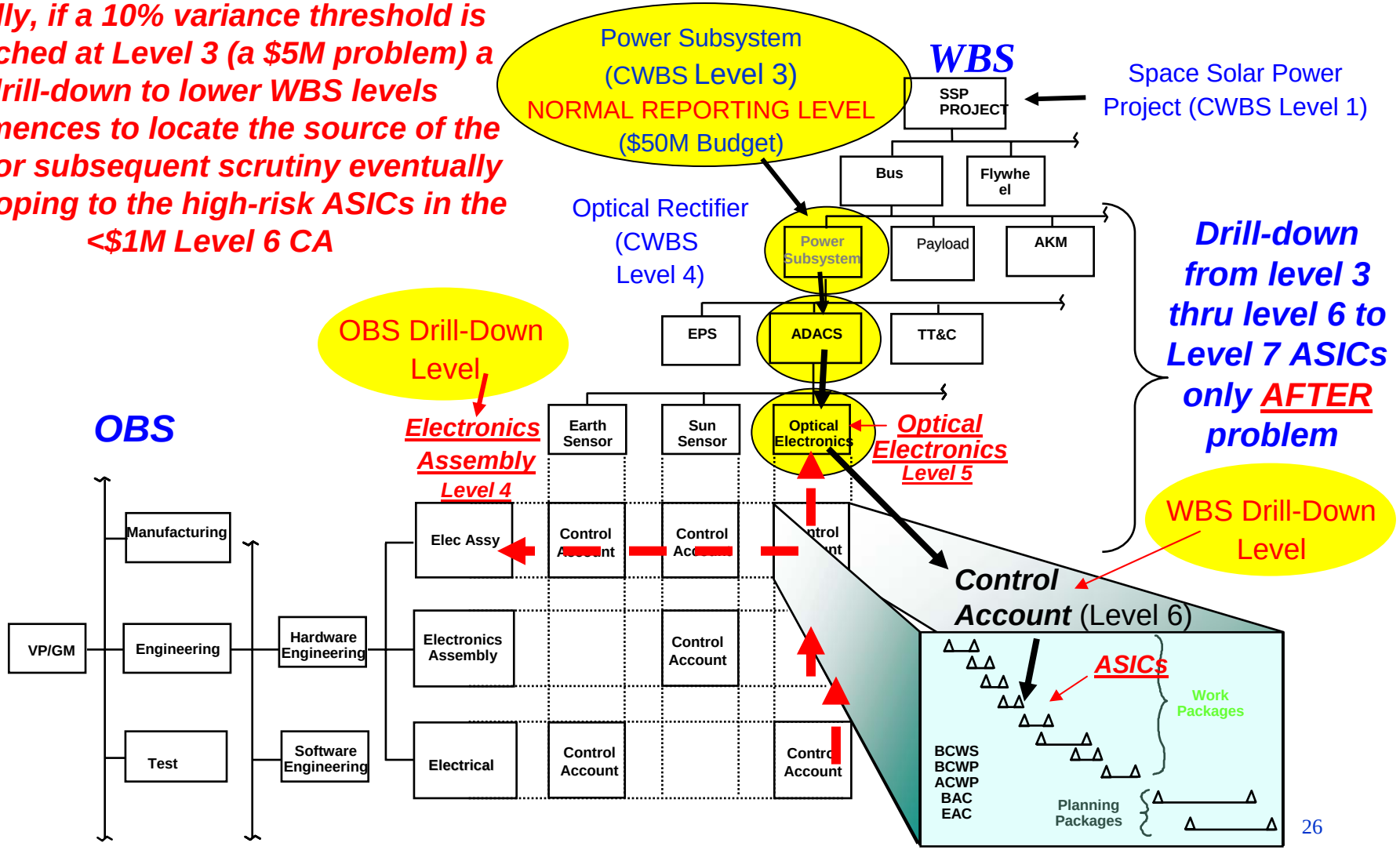
If WBS elements, other than those identified here, begin to experience variances exceeding 10% at one or two levels above the control account (source of risk) for two consecutive months in current month performance measurement, the contractor/performing organization will inform the Project Manager and a consensus reached on adding them to the group of high risk WBS elements identified for monthly cost performance reporting and analysis purposes.

All other WBS elements shall have earned value (BCWS, BCWP, ACWP) reported at level 3 of the WBS to satisfy observing and monitoring requirements

Traditional Level 3 Reporting

10% Variance Reporting

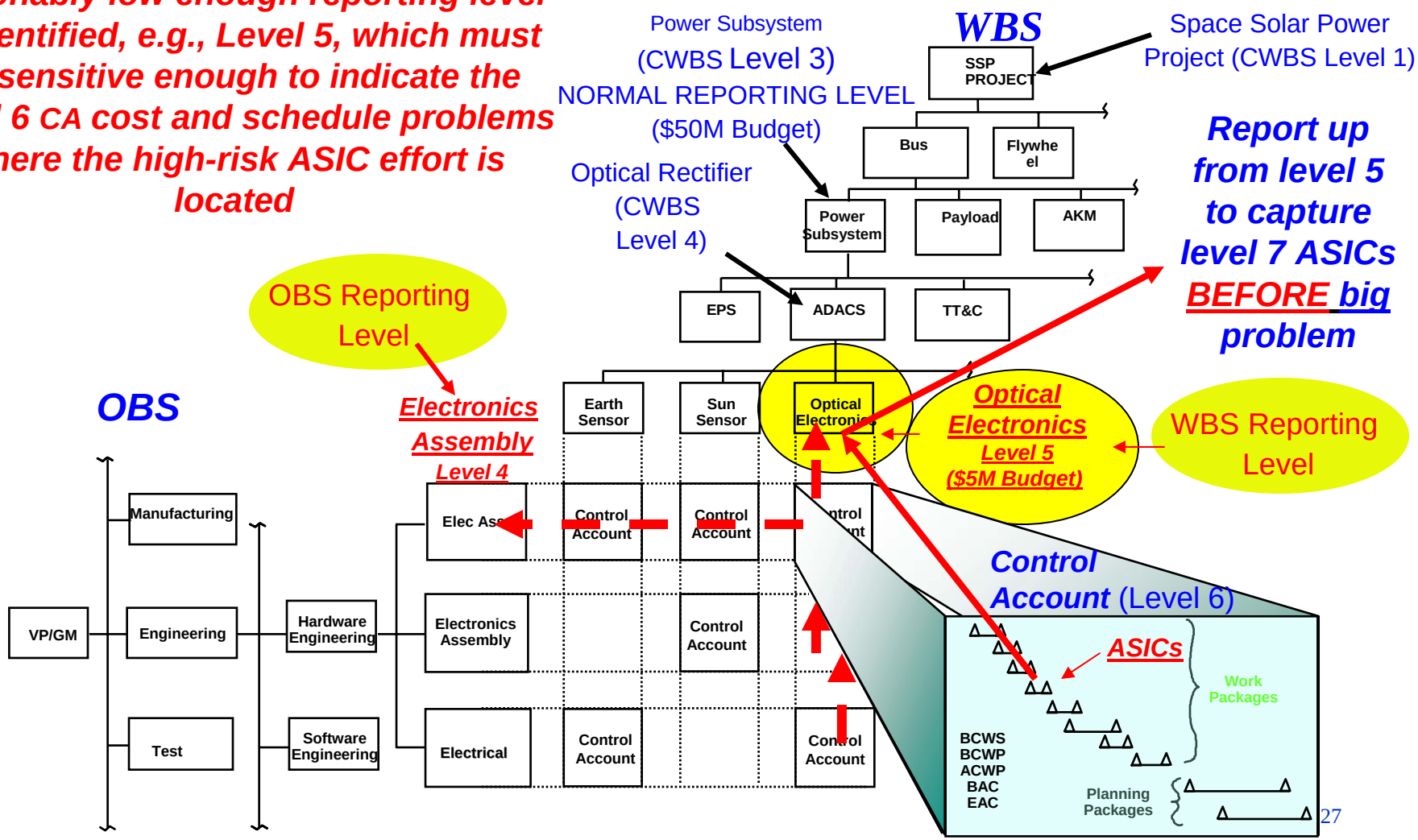
Normally, if a 10% variance threshold is breached at Level 3 (a $5M problem) a drill-down to lower WBS levels commences to locate the source of the risk for subsequent scrutiny eventually developing to the high-risk ASICs in the <$1M Level 6 CA



CCRM Med/High Risk Reporting

High-Risk No-Threshold Variance Reporting[3]

A reasonably low enough reporting level is identified, e.g., Level 5, which must be sensitive enough to indicate the Level 6 CA cost and schedule problems where the high-risk ASIC effort is located



[3]*Until risk is no longer a threat or is retired*

Cost Performance EVM Analysis

(CCRM Step 9)

CLASSIFICATION *(When filled in)*

COST PERFORMANCE REPORT
FORMAT 1 - WORK BREAKDOWN STRUCTURE DOLLARS IN _____ *Form Approved OMB No. 0704-0188*

1. CONTRACTOR	2. CONTRACT		3. PROGRAM	4. REPORT PERIOD
a. NAME	a. NAME		a. NAME	a. FROM *(YYYYMMDD)*
b. LOCATION *(Address and ZIP Code)*	b. NUMBER			b. TO *(YYYYMMDD)*
	c. TYPE	d. SHARE RATIO	b. PHASE *(X one)* RDT&E ☐ PRODUCTION ☐	

5. CONTRACT DATA							
a. QUANTITY	b. NEGOTIATED COST	c. EST. COST AUTHORIZED UNPRICED WORK	d. TARGET PROFIT/ FEE	e. TARGET PRICE	f. ESTIMATED PRICE	g. CONTRACT CEILING	h. ESTIMATED CONTRACT CEILING

6. ESTIMATED COST AT COMPLETION				7. AUTHORIZED CONTRACTOR REPRESENTATIVE		
	MANAGEMENT ESTIMATE AT COMPLETION (1)	CONTRACT BUDGET BASE (2)	VARIANCE (3)	a. NAME *(Last, First, Middle Initial)*	b. TITLE	
a. BEST CASE				c. SIGNATURE		d. DATE SIGNED *(YYYYMMDD)*
b. WORST CASE						
c. MOST LIKELY						

8. PERFORMANCE DATA

ITEM (1)	CURRENT PERIOD					CUMULATIVE TO DATE					REPROGRAMMING ADJUSTMENTS		AT COMPLETION		
	BUDGETED COST		ACTUAL COST WORK PERFORMED (4)	VARIANCE		BUDGETED COST		ACTUAL COST WORK PERFORMED (9)	VARIANCE						
	WORK SCHEDULED (2)	WORK PERFORMED (3)		SCHEDULE (5)	COST (6)	WORK SCHEDULED (7)	WORK PERFORMED (8)		SCHEDULE (10)	COST (11)	COST VARIANCE (12)	BUDGET (13)	BUDGETED (14)	ESTIMATED (15)	VARIANCE (16)
a. WORK BREAKDOWN STRUCTURE ELEMENT High Risk WBS	S	P	A	SV	CV	S	P	A	SV	CV			BAC	EAC	VAC
b. COST OF MONEY															
c. GENERAL & ADMINISTRATIVE															
d. UNDISTRIBUTED BUDGET															
e. SUBTOTAL *(Performance Measurement Baseline)*															
f. MANAGEMENT RESERVE															
g. TOTAL															
9. RECONCILIATION TO CONTRACT BUDGET BASE															
a. VARIANCE ADJUSTMENT															
b. TOTAL CONTRACT VARIANCE															

DD FORM 2734/1, AUG 96 PREVIOUS EDITION MAY BE USED. LOCAL REPRODUCTION AUTHORIZED.

CLASSIFICATION *(When filled in)*

HIGH RISK CONTROL ACCOUNT

						EV Techniques		0/100, 50/50, Units Complete, % Complete, Milestones			
	CONTROL ACCT. TITLE: **Optical Frequency Demodulator**					CONTROL ACCOUNT MANAGER: Joe Hamaker					
	BUDGET: $10,000										
	TIER I MILESTONE			CA Start					CA COMP		
WP#	WORK DESCRIPTION	EV METHOD		MONTH 1	MONTH 2	MONTH 3	MONTH 4	MONTH 5	MONTH 6	TOTAL BAC	
			BCWS					1,500		1,500	
1	**Procure Casing**	0/100									
			BCWP					1,500			
			BCWS			500	500			1,000	
2	**Optical Freq Receive**	50/50									
			BCWP			500		500			
			BCWS	600	600	600	600	600		3,000	
3	**OPT-RF ASICs**	units complete									
			BCWP	600	600	-	1,200	600			
			BCWS		1,000	1,000	1,000			3,000	
4	**DC Transformer**	milestone			1	2	3				
			BCWP		1,000	-	1,000	1,000			
			BCWS				500	500	500	1,500	
5	**Integration**	% complete									
			BCWP				-	300	1,200		
TOTAL CONTROL ACCOUNT PLAN			**BCWS**	600	1,600	2,100	2,600	2,600	500	10,000	
			BCWP	600	1,600	500	2,200	3,900	1,200	10,000	
	Schedule Variance	month		0	0	-1,600	-400	1,300	700		
		cumulative		0	0	-1,600	-2,000	-700	0		
	Actual Costs			700	1,700	1,300	2,300	5,200	2,100	13,300	
	Cost Variance	month		-100	-100	-800	-100	-1,300	-900		
		cumulative		-100	-200	-1,000	-1,100	-2,400	-3,300		

SUMMARY

Incorporated in NPR 7120.5C

Preparation
Cost-Risk Feedback: Steps 1-5

Development
Cost-Risk Feedback: Steps 6-8

Application
Cost-Risk Feedback: Steps 9-12